

On some Mineral Constituents of a Dusty Atmosphere.

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During the past 12 months I have had occasion to ascertain the nature of the mineral constituents of an ordinarily turbid atmosphere. By means of a small portable quartz spectrograph several series of spark spectra were photographed with graduated exposures of 1, 5, 10, 20, 40, and 60 seconds, all on the same plate. The electrodes in the first series were cadmium, iron, nickel, and copper, a self-induction coil being interposed to eliminate the air spectrum and the short metallic lines.

Several plates taken from only the cadmium electrodes exhibited features of particular interest when minutely examined. Though the spectra are small, the instrument gives fine definition from the red potassium line about $\lambda 7665\cdot6$ to that of cadmium $\lambda 2194\cdot7$.

With Wratten and Wainwright's panchromatic plates, an exposure of one second renders all the principal lines of cadmium, including $\lambda\lambda$ 4800 and 2265, with 10 seconds all the rays from $\lambda 6438$ are obtained. The solar spectrum from *b* to *M* is faintly visible at all exposures from 1 to 60 seconds inclusive.

The conspicuous H and K lines seen in the first three exposures have their usual appearance; but, on the third spectrum, exposed 20 seconds, the K line has, at its exact centre, an extremely narrow sharp black line; in succeeding exposures this line becomes longer and intensified.

With 40 seconds' exposure a similar black line is just discernible on H, and it is stronger with 60 seconds. Other parts of the solar spectrum are overlaid by exceedingly fine dark lines which it was proved do not belong to the cadmium spectrum, but were caused by solid matter in suspension in the atmosphere being vaporised by the spark. The dark lines on H and K are easily explained by the presence of calcium carbonate in very minute particles of dust suspended in the air. I have called attention to this in former publications.* It was proved in these experiments that the lines did not originate from impurities in the metallic cadmium, because the same electrodes with longer exposures yielded spectra without any impurity lines, when the sparks were passed in an atmosphere of hydrogen. It was also found that whether in the open air, or in a quiet room near a window, the most prominent lines of calcium were always present.

* Hartley, 'Phil. Trans.,' 1884, Part I, pp. 49—62, and Part II, pp. 325—342. Also 'British Association Report, Aberdeen,' 1885, and 'Journ. Soc. Arts,' 1886, pp. 396—415.

A line, rather more refrangible than G, was carefully measured, and proved to be that of calcium, λ 4226.9; it is the *ultimate* line of the element in oxyhydrogen flame spectra.

There are two lines just on either side of M; there is no doubt that these are the calcium lines $\lambda\lambda$ 3737.2 and 3706.3.

It has been shown by Hartley and Adeney's wave-length determinations* that the line of cadmium measured by Mascart (No. 12) is a triple line, the components being distinguished by the following letters and wave-lengths:— α 3261.2, β 3252.6, and γ 3250.5. With a self-induction coil the β line disappears. On examining plates photographed on three successive days, with exposures varying from 1 to 60 seconds, it was seen that two plates showed only two lines α and γ . The third plate showed, at an exposure of one second, an extremely fine and very sharp black line, more refrangible than the other two, which, by very careful measurements, was proved to be the ultimate line of copper, λ 3274. With five seconds' exposure this and all other succeeding spectra on the plate showed another line less refrangible than the cadmium group, which was proved to be the penultimate line of copper, λ 3247.7.

A comparison of the plates of spectra showed that with the same exposures on each succeeding day the five lines of calcium and the two lines of copper became stronger; in other words, the increased strength of the lines showed that the outside air became more dusty. This was seen to be actually the case, under the conditions of a dry atmosphere and a hot sun continuing for six or seven days in the month of May.

To ascertain the origin of the copper was an enquiry attended with some difficulty, the quantity diffused in the atmosphere of the city being comparatively large.

Copper has been proved to be a constituent of coal ashes, and of the flue-dust from gasworks and chemical works, of soot, and of dust from the clouds in hail, snow, and sleet.† These sources, however, contain other constituents, notably lead, nickel, and iron.

The constant traffic of tram-cars and motor-cars in the street raised dust, which caused an increased haziness of the atmosphere day by day, and corresponding increase in the number and intensity of the calcium lines in the spectra.

While making these observations, the prevalence of copper in the dust was accounted for by the repeated flashes on the overhead cable, which is in the centre of a wide street (St. Stephen's Green) at a distance of 54 feet from the

* 'Phil. Trans.' 1884, Part I.

† Hartley and Ramage, 'Roy. Soc. Proc.,' 1901, vol. 68, p. 97.

window of my private room. The condensation of the vapour of copper after each discharge must yield a dust of extreme tenuity such as could not arise from mechanical action, such as scraping or abrasion of the solid metal.

The lines identified from their proximity to, or coincidence with, solar lines, are as follows; the wave-lengths of calcium are taken from Eder and Valenta's spark lines :—

	λ	λ	
Near G	4308	4226·9	Calcium.
H } Coincident		3968·6	} Calcium.
K }		3933·3	
Near M	3727	3737·2	} Calcium.
		3706·2	
Near Q	3284·7	3274·0	} Copper.
		3247·7	

Of seven plates of spectra photographed in the months of April and May two were very carefully measured with the micrometer. Twenty-two lines were positively identified with those of elements known to be contained in atmospheric dust. The lines are principally the ultimate lines of the respective elements.

The following is a list of the wave-lengths found and the wave-lengths adopted :—

Wave-lengths found.	Wave-lengths adopted.	Origin of lines.
4227·5	4226·9	Calcium.*
4058·5	4057·8	Lead.*
3965·5	3968·6	} Calcium.*
3932·5	3933·8	
3878·0	3876·2	} Carbon.
3870·0	3871·2	
3733·0	3735·0	Iron.*
Very faint.		
3683·5	3683·1	} Lead.*
3643	3639·7	
Very faint.		
3495	3496	} Manganese.
3484·5	3483	
3416	3415	Nickel.*
3274·8	3274·0	} Copper.*
3247·9	3247·7	
2802·1	2802·4	} Magnesium.*
2794·5	2794·5	
2614·5	2614·8	Lead.
2594·0	2594·0	} Manganese.*
2575·0	2576·2	
2480·0	2478·7†	Carbon.*

* Ultimate lines.

† A. de Gramont, 'Comptes Rendus,' 1908, vol. 146, p. 1260. This line appears distinctly with an exposure of 60 seconds, but as a short line. Of the other two lines one corresponds with λ 3876·5, Liveing and Dewar, the other with 3871·5, Kayser and Runge, and 3872, Eder and Valenta, the second edge of the cyanogen band No. 3. See 'Proc. Roy. Soc.,' 1896, vol. 60, p. 216. The first edge 3883·8 is obscured by a nitrogen band.

Spectra were photographed from portions of the same cadmium electrodes, six months later, in a part of the college as far removed from the frontage as possible, close to a large garden, and with no street thoroughfare within 100 yards.

There had been heavy rain, which had washed out much of the dust from the air. Notwithstanding, the wave-length measurements of two feeble strange lines identified them with copper, and the five calcium lines were very distinct.

Spectra were photographed from cadmium electrodes in hydrogen with exposures of one, two, three, and four minutes; cadmium in air exposed one minute. The spectrum taken in the hydrogen atmosphere, and exposed *four* minutes, was in all respects of similar intensity to that taken in air in *one* minute, except beyond λ 2418.5, where the continuous rays between the lines commenced to fade away. The spectra taken in hydrogen showed no trace whatever of the lines of either copper or calcium, and many other feeble lines were entirely absent which undoubtedly are representative of the other constituents of atmospheric dust. It is thus proved, absolutely, that the copper and calcium were the constituents of dust diffused through the atmosphere of the city.

Determinations of the weight of material necessary to give the lines of these spectra in the manner described, and with such short exposures, have been completed. From the loss of weight of the dry electrodes by the passage of the spark during successive intervals of 10 minutes, the weight of metallic calcium volatilised in one minute, and in one second, was calculated. The number of spark discharges per second was accurately determined, and likewise the number of discharges necessary to render the lines of calcium, as photographed from atmospheric dust, with an exposure of 60 seconds. Similarly with copper, the number of discharges necessary to render the *ultimate* line and the two lines respectively, as measured on plates exposed to atmospheric dust for one second and for five seconds, was ascertained, and the weight of copper volatilised at each spark discharge was accurately determined. It was found that, in order to render the five principal lines in the spectrum of calcium, the weight of the metal passing between the electrodes in 60 seconds was from 0.0001 to 0.00014 mgrm., or, as calcium carbonate, from 0.00025 to 0.00035 mgrm. Similarly, the quantity of copper which passed between the electrodes in one second was from 0.0005 to 0.0007 mgrm., and in five seconds from 0.001 to 0.0014 mgrm. These quantities yield the spectra photographed, and the proportion of copper in the dust thus appears to be 10 times as great as that of the calcium.

Both the calcium and copper reactions in the spark are more delicate than

the sodium test by the yellow flame, or even by the photography of the *ultimate* lines of sodium in the oxyhydrogen flame and spark. Metallic sodium renders no lines with one spark when photographed, and with five sparks the lines $\lambda 3301.1$ and $\lambda 3302.5$ are both stronger than the yellow lines (mean $\lambda 5893.2$). These lines do not appear on any of the cadmium plates.

The reactions of lead, manganese, and magnesium in the spark are much more sensitive than those of sodium, calcium, or copper. For instance, 0.00003 mgrm. of manganese is volatilised by one spark discharge, and yields a spectrum with the following *ultimate group* of lines: 2949.3, 2939.4, and 2933.1.

As no atmosphere is free from dust, and that of cities is particularly dusty, these mineral constituents must be regarded as possible reagents in cases where there is evidence that very minute quantities of basic substances can initiate chemical reactions and isodynamic changes, such as have generally been considered as spontaneous, and in all cases where a solution in contact with air is liable to be affected.

*On the Absolute Measurement of Light: A Proposal for an
Ultimate Light Standard.*

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The measurement of the intensity of a source of light is, it is well known, a somewhat unsatisfactory process. The eye cannot estimate light intensity; it can only tell when the illumination of two adjacent surfaces is equal. If, for example, we desire to measure the intensity of a metal filament lamp, we compare it with a Hefner lamp and say that the intensities are inversely as the squares of the distances from the photometer head, when equal illumination is obtained. In strictness, however, this method is applicable only when the colours of the two sources, or more accurately when the distribution of energy in the spectra of the two sources, is exactly the same; for the relative luminosity of the different colours of a spectrum varies with the intensity of that spectrum. Abney has two well-known curves illustrating